can often be studied to greater advantage than by the naked eye alone. The track of every bright meteor should be examined with such a telescope to determine if a faint persistent train remains. It is probable that in this way many persistent trains can be discovered which would not be observed by the naked eye. Moreover, Mr. Denning has shown that a great many meteors are visible in a telescope which are invisible to the naked eye, and he also gives instances where persistent trains of these telescopic meteors have been thus detected. It would also be of great value to use a mounted telescope having a micrometer eyepiece or some device by which the width of the trains could be measured to a fraction of a degree accurately. The same instrument would be of service in locating the position of the train and determining in an accurate manner the rate of drift. Also, since the streak-bearing meteors are fairly well known, watches at adjacent observatories near enough for a good base line could be maintained for the few nights of the year when these meteors occur, for the purpose of doubly observing the train drifts and determining the height of the trains. It is hoped that a definite plan can be formulated for the systematic observation of meteor trains in the future, because they provide the only means by which data concerning the extreme upper regions of the earth's atmosphere can be obtained.

The physicist, by the aid of laboratory experiments, may be able to work out the solution of the meteor-trains problem, but the facts of the phenomena must be observed by the astronomer. The following suggestions are made because it has been found that many records of the past which might have been very valuable have been made of little use by the omission of details in the published reports. It therefore becomes necessary to point out what facts of a meteor-train observation are most important. The facts to be recorded are placed under two headings, because the statements in regard to the meteor nucleus or hot moving body and its train of sparks must be clearly distinguishable in the records from those relating to the true train or streak which remains visible for many seconds or minutes. In many reports there has been confusion in this respect. A third heading might cover various other facts which need not be considered at the time of the observation of the train, but which nevertheless are essential for a complete record. Every one of the following points are important in the record of the observation of a meteor train if they can be noted. *A high degree of accuracy is, however, of the first importance even if it is necessary that the observation be confined to but a few features of the train.*

A. *Observations concerning the meteor nucleus.*

(1) Time of appearance of meteor nucleus and of duration of its flight.

(2) Radiant point and name of meteor (Leonid, Perseid, etc.).

(3) Color of nucleus, length of track, and length of portion of streak with respect to the entire track.

B. *Observation of the persistent train or streak.*

(4) Color of train immediately *after* disappearance of nucleus and *any change of color* of the train during the time that it is visible.

(5) Length and width of train, in degrees and minutes of arc, immediately after disappearance of nucleus, and its position in the heavens with respect to easily identified stars.

(6) Observations, at short intervals of time, of the change of dimensions of the train in degrees, accompanied by a series of the drawings, if possible, indicating the successive changes in shape of the train. *The width of the train*, or a portion of it, *at successive intervals of time*, is of the greatest importance, since it indicates *the rate of diffusion of the gaseous mass.*

(7) The displacement or drift of the train in degrees, with corresponding time. For this purpose some *bright portion of the train* should be selected *when the train is first seen.* Also the direction of the drift with *respect to the earth's surface*, and if calculations are made of the rate in miles, they should be so stated.

(8) If the intensity of light of the train is (1) uniform, (2) brightest on the outside, or (3) brightest at the center, and the time of this observation after the first appearance of the meteor.

(9) Whether the train increases in brightness, this effect appears to occur not infrequently. The observer should be careful not to mistake an increase in the dimensions of the train for an increase in intensity.

(10) Spectroscopic observations, looking for the presence and position in the spectrum of one yellow line and one or two lines in the green.

(11) How long the train is visible to the naked eye and how long visible in the telescope.

Systematic and accurate observations of persistent meteor trains will in all probability lead to results of much practical value. It is within reason to hope that light may be thrown on the following problems: (1) The cause of the apparent self-luminosity of the meteor train; (2) the height of the earth's atmosphere, by accurate measurement of telescopic trains; (3) the density of the earth's atmosphere at an altitude of 50 to 65 miles, by a direct comparison with the pressure at which gas phosphorescence can occur if the meteor train is an "afterglow;" (4) the direction and velocity of currents in the atmosphere at great altitudes; (5) the possible relation of atmospheric motion at high altitudes to barometric pressure, and some other facts which seem indicated by the statistical work done by the writer which require further data for confirmation.

TRANSFORMATIONS OF SNOW CRYSTALS.

By A. ERMAN. Dated, 1859.

The following extract, here reprinted from the London Philosophical Magazine, 1859, **17** (4th series): 410–413, presents some observations on the transformations of snow crystals, made by A. Erman during his trip around the world. They were published in his Reise um die Erde[1] and translated by him for Tyndall, who published them in the above journal. We omit the figures given in the London Philosophical Magazine.—*C. A.*

May 13, [1829?] Latitude 60° 40′, longitude 138° 57′ east from Paris, at 2580 Parisian feet (2749 English) above the sea.—I had begun immediately after noon to measure solar altitudes, when a number of light clouds began to form and then to be driven fast by the west wind. The air cooled down (from about +3° R. [38.8° F.]) to +1° R. (34.2° F.), and snow fell for sixteen minutes; then the clouds dissolved again, the evening became clear, and the cold increased in the night to −5° R. (20.8° F.). I have never seen snow in more perfect and variously formed crystals than during this short and sudden shower. Each grain fell single, and among the few which settled on the glass or the metal of my instruments, I could distinguish six different forms. Doubtless many more remained unobserved, for my attention was drawn in the meantime to a more wonderful and quite novel phenomenon. Many of the crystals began to melt the instant they touched a solid body, and some, as it seemed to me, melted while still falling thru the air; but in the next moment this was followed always by a new congelation, the grain of snow assuming, not its previous form, but another more complex. Thus, for instance, the most simple crystals which I observed to-day, consisting of six thin needles of ice, which adhered to each other like the diagonals of a regular hexagon (fig. 2*a*). When melting, each single ray of this star contracted into a thicker cylinder of water, having about half of its former length

[1] Ermann: Reise um die Erde, 1835–1849, Hist. Abth, **2**:395; or the English translation, abridged, Travels in Siberia. London, 1848. **2**:501.

(fig. 2*b*); but after a few moments these cylinders were seen to congeal again, and change thereby into broader plates, sharpened at their outer edges by two planes of a regular hexagonal prism. The whole crystal became thus again a hexagonal star, but with broader and shorter rays than it hadbefore.

Other crystals, which had at the beginning such flat and broad rays (fig. 2*c*), changed these by melting into feathered ones (fig. 3*c*), because on their liquefaction there remained only the middle of each plate, like an icy needle, in the water, until, the new congelation ensuing, a number of needles ran at each side out of this rib at angles of 60 degrees.

Some of the stars were feathered in the beginning, but only at the outer half of their rays. I did not see any change take place in them, nor did this happen with some other more complicated forms. Thus I observed among others a small and continuous hexagonal plate, with simple rays issuing like diagonals out of its angles; but then each adjoining pair of these rays was still connected by a couple of needles which met at an angle of 60 degrees (fig. 4).

But these complicated forms were comparatively rare; and those transformed under my eyes were so predominant, and presented a spectacle so full of motion, that at last I could hardly help comparing them with living beings. In fact it is only in the case of such that we are accustomed to witness changes so mysterious without inquiring after the forces that produce them. We got, however, a partial explanation of this phenomenon by remarking that the outer parts of the snow-crystal, which were the first to melt, borrowed their warmth of liquefaction from the parts that remained solid, and thereby cooled these below the point of congelation. The newly-formed water could then freeze again by its collecting round this cold ice, and by its offering at the same time a smaller surface[2] to the air whose temperature had melted the crystal. This water then assumed in freezing a more complicated form, because the remainder of the old crystal exerted in it a greater variety of attraction than that which occurs in a wholly liquid drop. Perhaps all complicated forms of snow [crystals] result from the simple one by melting and freezing again in this way, a process which they must then undergo during their fall thru the air; and here this hypothesis seemed somewhat confirmed by the complicated crystals being always of less diameter than the simple ones.

Additional remark (April, 1859).—I have sometimes watched the snow-crystals which fell at Berlin when the temperature of the air was a little higher than the freezing-point, but till now without seeing again the phenomenon just mentioned. We may suppose either that these observations were still too rare to present some one of those neglected and apparently trifling circumstances that are requisite for the phenomenon in question, or that this depended also on the spot where I made my first observation having been at a considerable elevation, and consequently not far from the atmospheric stratum where the snow was first formed. But then, as to the explanation of the observed metamorphosis of snow, I think it might have some connection with the equally obscure property of some chemical precipitates, which, like carbonate of lime, according to M. Ehrenberg, consist, when first consolidated, of regularly arranged solid globules, and which are then changed, "all of a sudden and quite wonderfully," to aggregates of true crystals of microscopic size. (Cf. Ehrenberg in Abhandlungen der Berliner Akademie, 1840.)

THE CRYSTALIZATION OF UNDERCOOLED WATER.

By BORIS WEINBERG. Dated St. Petersburg, July, 1908.

[Reprinted from the Physical Review, 1908, 27:509-510.]

In order to show the undercooling of water and to allow the free development of its crystals I endeavored to introduce into the undercooled water a piece of ice put in a finely drawn out glass tube. The experiment, carried out the first time by Michael Tvanov, gave an unexpected result. When the crystallization attained the end of the tube there began to grow at this point an ice crystal having the shape of an hexagonal star and very similar to the characteristic snow crystals.

The greater the undercooling of the water the more numerous were the ramifications and the greater the velocity of crystallization. With water undercooled to a temperature between —0.3° and —1° C. I obtained small stars with few narrow ramifications, see fig. 1. Undercooling to a temperature between —1° and —3° C. gave rise to stars with such dense ramifications that they resembled hexagonal plates, see fig. 2. The plane of the stars contains the direction of the end of the tube, and therefore when this end is vertical a sufficiently large plate can divide the tube into two parts. An undercooling greater than —3° C., especially when the end of the tube is not narrow enough, produces several plates set in different azimuths, and the whole mass becomes at last a mass of differently sized crystals and water, resembling the so-called "anchor ice."

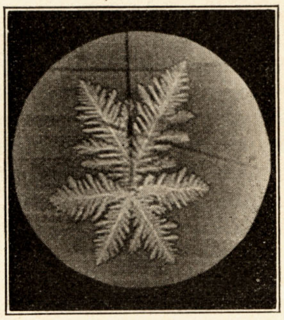

FIG. 1.

The crystals are often a conglomeration of several stars which have their planes, their principal rays, and even the ramifications of higher order parallel as in fig. 3.

If a star is broken, the pieces of it rise horizontally in the water with slight oscillations and attain the surface. This circumstance can explain the verticality of the optic axis by river and lake ice.

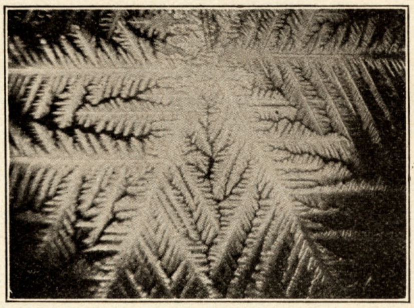

FIG. 2.

The evolution of these artificial snow crystals can be easily projected on a screen, if the vessel (a tumbler, an alembic, an evaporating dish) with undercooled water is put into another vessel with plane-parallel sides containing water at a temperature somewhat higher than the thaw temperature [dew-point?] of the surrounding air. For undercooling any water can serve, but the refrigerating mixture (finely chopped ice upon which is poured a strong solution of NaCl) must not be too cold (from —4° to —6° C.) and its level must be lower than the level of the water which is to be undercooled.

The projection is especially beautiful when the vessel is placed between crost nicols, as in figs. 1–3. A star on a

[2] Viz, the *curved* surface of a single, or of six connected drops.